

constraints that can lead to the best plan accounting for the anatomical specificity of each single patient. The knowledge based planning processes aim on one side to train an engine with the prior knowledge on plan-goodness coming from patients already planned, whose plan quality is at the highest level; on the other side, based on that knowledge, to generate the proper dose-volume constraints to be used in the optimization (inverse planning) process. Such constraints would include the prior knowledge, together with the specific anatomy of the new patient.

Different mathematical approaches have been explored, to possibly bring the knowledge-based-planning concept available to the radiotherapy community. Some approaches will be here explored, and specific examples will be evaluated to understand the possible benefits and perspectives of such a planning modality. The specific sites will be the prostate, the head and neck, the lung, the breast. The knowledge-based-planning approach showed evidence of improved plan quality, reduced inter-clinician inter-planner variability. Another key point would be the possibility in the future to transfer the planning expertise from more experienced centres to less experienced institution, in a frame of sharing knowledge.

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Automated plan generation

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Treatment planning is a labour-intensive time-consuming task, with quality highly dependent on the skills and experience of the planner, and on the software used. For a human planner, considering more than 5 competing criteria/organs-at-risk is challenging, while most sites easily contain 15+ criteria. Additionally, there is a large degree of freedom in treatment device setup, and even in the selection of the treatment modality. To ensure generation of high-quality treatment plans and personalised healthcare, treatment plan generation should be automated. This also allows for large-scale treatment planning studies, and is an important element in online adaptive radiotherapy.

Automated treatment planning is based on an *intelligent decision-making system* which is capable of mimicking the human decision-making. Erasmus-iCycle uses a knowledge-based wish-list, where treatment goals for the objectives are prioritised and sequentially processed. The intelligence lies in a flexible system to efficiently explore the large search space of possible plans for an individual patient based on a predefined protocol. The prioritisation allows to incorporate many structures to be optimised upon. For example, the dose to the swallowing muscles can be minimised without risking an increase of dose to the more important salivary glands, or compromising target coverage.

When optimally integrated in the *clinical workflow*, the manual interaction is minimal. The user selects a protocol for the current patient, and the plan optimisation is started. The next interaction is then with the physician, who ideally only has to approve the final plan. This can only work if the automatically generated plans are of consistent high quality, and manual adaptation of the plan would only lead to minor improvements.

Automatically generated plans have the property that they are planner independent, reproducible, of consistent quality and require no hands-on time. This allows to perform large-scale *planning studies* where different protocols, class-solutions, approaches and/or modalities can be quantitatively compared. Is it possible to improve treatment for patients

with bilateral metal hip prosthesis when using non-coplanar irradiation? Is a certain class-solution an alternative for full beam angle optimisation? Does VMAT always result in higher quality than a static beam setup? Does the inability to use posterior beams with the CyberKnife limit plan quality? Does protocol X result in more preferred plans compared to protocol Y? The answer to these questions can now be investigated with a minimum of planning workload.

Another step in improving treatment quality is *online adaptive radiotherapy*. A prerequisite for successful clinical implementation of online planning is a guaranteed high quality plan, as there is no time to modify the plan online. With automated planning this requirement is already met, but the optimisation has to be fast. A more relaxed approach is using a plan library. Based on predictions on internal organ motion, personalised plans for different scenarios can be computed offline, which is feasible as the planning is automated. At each fraction, the best matching plan is used from the database.

With the possibility to generate plans without manual interaction, it is affordable to make plans for different setups or modalities for each individual patient. One could for example compute plans for 9 and 12 beam coplanar setup, non-coplanar, VMAT, or compare photon and proton plans on a per patient basis. This allows for the next level of *personalised radiotherapy treatment*, where only patients who benefit most from a complex treatment receive it.

Debate: Online position verification is mandatory for all tumour sites

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For the motion

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Against the motion

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Over recent years, daily online imaging has become increasingly commonplace across many sites treated with radiation therapy. Image guided radiation therapy (IGRT) aims to improve the geometric accuracy of treatment delivery, ensuring that the target volume receives the prescribed dose as planned, while more effectively sparing surrounding normal tissue. This is ultimately intended to improve clinical outcomes of patients with regard to tumour control and/or treatment-related toxicity. Given the trend towards more frequent imaging, is there justification for mandatory daily online verification across all treatment sites? IGRT is most commonly performed using 2D (MV or kV) or 3D (CBCT) radiographic imaging modalities. These imaging procedures however, come at a cost. Firstly, the dose administered from each procedure, while often minimal in a single instance, can accumulate to amounts that must be considered for risks of secondary tumour induction. It should also be remembered that the anatomical regions imaged typically far exceed the treatment volume. The latency of these consequences makes it difficult to evaluate the harm of IGRT workflows, as the technology has been so recently implemented. Secondly, there is a cost with regard to resources when implementing IGRT. Most clinical